Battery Charging on USB

Harry Baggen

Besides being handy for connecting and disconnecting equipment while the computer is running, USB includes a built-in supply line that can provide a certain amount of power to connected devices. That can be handy for quickly charging a battery when you can't find a real charger.

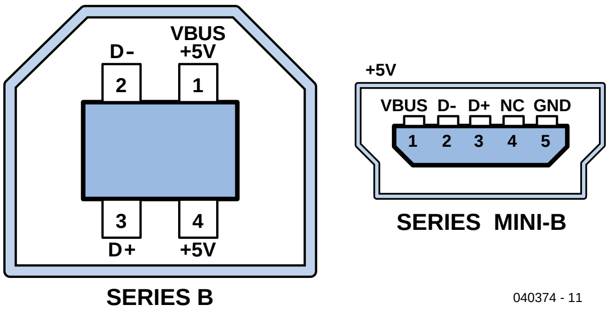

Figure 1. Two commonly used types of connectors for USB ports on peripheral devices.

Nowadays every computer has several USB ports, which have taken over the task formerly handled by the RS232 bus. USB cables have different connectors at each end to prevent incorrect connections. **Figure 1** shows types of device receptacles, which are used in peripheral equipment.

A USB connection has only four lines, consisting of a data line in each direction, a ground line, and a supply line. The supply line can be used to power peripheral devices. The host device (a PC or notebook computer) can source a maximum of 500 mA from each USB port. In USB terms, this is called five unit loads. A hub with its own power supply can provide the same amount, but a bus-powered hub can provide only one unit load per port. However, the host will only provide a current of 500 mA after communication with the connected USB device. Immediately after a connection to a USB device has been established, the device cannot draw more than 100 mA from the bus. The host does not decide whether to allow the device to draw a maximum current of 500 mA until the identification phase ('enumeration') has been completed.

Simple devices actually do not need this enumeration, as long as they ensure that they don't draw more than 100 mA from the bus. This can be exploited to simply tap off a bit of current from a USB port without causing the computer any problems. Some examples are mini-lamps and small fans with USB cables, which are currently sold for use with notebook computers. They 'misuse' the USB port in exactly this manner.

This 100 mA can also be used to charge a couple of batteries when you don't have a real charger to hand. That's very easy to do, as can be seen from **Figure 2**. A diode and a resistor are sufficient for charging two AA (penlight) or AAA cells connected in series, either NiCd or NiMH. It takes a while, since you're limited to a current of 100 mA, but in an emergency it's a perfectly good solution.

The component values for the circuit assume that the supply voltage on the USB line has a nominal value of 5 V and a minimum value of 4.5 V. The diode is for protection, to prevent damage to the USB port if the batteries are connected backwards. Resistor R1 is dimensioned for a current of approximately 90 mA through the two NiCd or NiMH cells. They can handle this for days on end without becoming overcharged, but it also means that they can't be fully charged in just a few hours. But once again, this is intended as a makeshift solution.

Professional products

Various semiconductor manufacturers have now developed special products for charging batteries using a USB port. Some of them are intended to be used for charging lithium-ion batteries, but that's not particularly interesting for DIY circuits, due to the difficulty of obtaining that type of battery.

Maxim has developed an idea for powering a circuit from a single NiMH cell that can be recharged from the USB port. **Figure 3** shows such a design using two Maxim ICs. The MAX1692 (U1) is a DC/DC step-down converter with current limiting. It charges the NiMH penlight cell (B1) from the USB supply line at a current of 300 to 400 mA. Although the converter is not actually a true current source, it is good enough (even with a shorted cell) to effectively charge the battery. The advantage of using a DC/DC converter is that the current drawn from the USB port is only 150 mA when the NiMH cell is being charged at current of 400 mA. This leaves 350 mA for directly powering the connected device, in addition to the charging current. The second IC, U2, is a DC/DC boost converter (MAX1722) that transforms the voltage from the single rechargeable battery back to 3.3 V. When the battery is being charged, this converter is disabled and the output voltage is 4.7 V (derived from the USB voltage via diode D1). The drawback of the charging circuit in Figure 3 is the absence of overcharge protection; the user must manually disconnect the circuit from the USB port when the battery is fully charged.

Protection

The USB specifications do not make any clearly defined statements regarding protection of USB ports. Some PC manufacturers provide reliable electronic current limiting for each port, while others only provide simple fuses on the circuit board. It is thus pos-

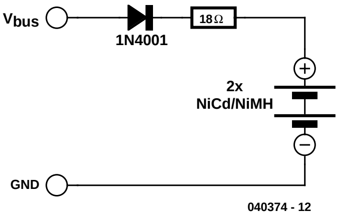

Figure 2. Two NiCd or NiMH batteries connected in series can easily be charged using a diode and a resistor.

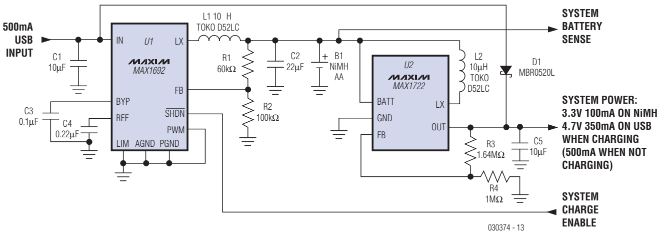

Figure 3. This Maxim design uses two DC/DC converters to charge a NiMH cell and power the connected circuit with a supply voltage of at least 3.3 V.

sible to 'blow up' a USB port if you try to draw too much current from it. National Semiconductor has developed a special IC that protects host ports against excessive output currents. The block diagram of this IC (LM3525) is shown in **Figure 4**. As soon as the output voltage drops more than 100 mV below the input supply voltage, the output current is limited to 1 A by the built-in power FET. Even with simple charging circuits such as the one shown in Figure 1, it's a good idea to include an LM3525 between the USB connector and the charging circuit, in order to prevent damage to the PC or notebook computer.

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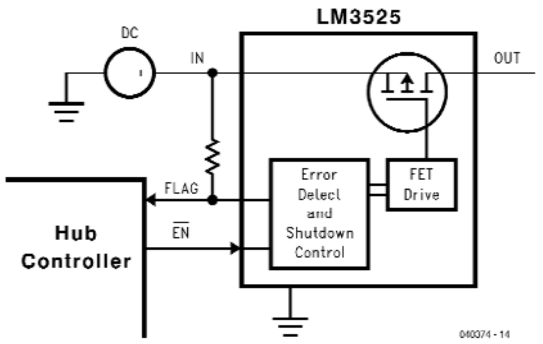
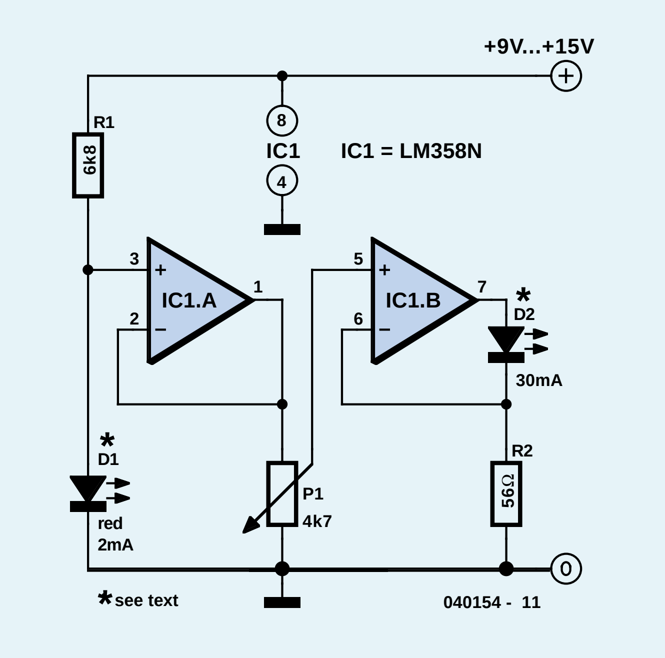


Figure 4. The National Semiconductor LM3525 provides a simple solution for protecting USB host ports against overloads.

30-mA LED Dimmer

Eberhard Haug



If you've ever tried dimming a LED with a simple potentiometer, you know that the approach does not work very well. Just as with ordinary diodes, the voltage-current characteristic of LEDs is far from linear. The result — depending on the potentiometer setting the LED brightness will hardly change most of the time as the pot is turned and a sudden variation at the end.

The best method to tackle this problem is to power the LED from a current source with zero to 100% adjustment range. The circuit shown here is an example.

A low-current LED (D1) is used to generate a reference voltage that's first buffered by one half of an LM358. The actual current source that powers the LED(s) is built around the second opamp in the chip.

The potentiometer allows the output current to be adjusted, with R2 acting as a current sense, the resistor dropping the same voltage as the one obtained from the pot. Using Ohm's law we find that the maximum current through R2 amounts to about 29 mA ($I_{LED} = 1.6\ \text{V} / 56\ \Omega$).

If necessary, the current may be adapted to suit other LED types, for example, 20 mA is obtained with R2 = 82 Ω and 10 mA at R2 = 150 Ω.

It is also possible to connect several LEDs in series. The total voltage available for the LEDs is determined by the voltage drop across series resistor and the opamp, and, of course, the supply voltage. In this way, the highest number of LEDs may be found from $U_{LED,\ total} = U_{batt} - 5.1$ V. In principle, it is possible to increase the supply voltage to 30 V in order to connect even more LEDs in series. This does, however, call for the value of series resistor R1 to be increased to prevent overloading the low-current LED used in the voltage reference.

If you intend to experiment with larger numbers of LEDs (say, in arrays) then the maximum loading of the opamps becomes an issue. The DIP version of the LM358 may dissipate up to 830 mW. The power, P, is calculated from $P = U_{batt} - 1.6 - U_{LED,total} \times I_{LED,max}$

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